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Gypsy Moth News

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Slowing the Spread of the Gypsy Moth

Donna Leonard

Facts about the Gypsy Moth

. Since its introduction into the United States in 1869, the gypsy moth has spread to all or part of 17 States and the District of Columbia.

. The area already infested represents only 25 percent of the total area that will be susceptible to outbreaks as the insect spreads.

. Gypsy moth defoliates trees; affects water quality; alters wildlife habitat; and impacts timber, tourism, and recreation.

. Gypsy moth damage often occurs in forested neighborhoods and urban parks where dead trees are a safety hazard.

. Gypsy moth affects commerce because commodities shipped to uninfested areas must be certified to be free of gypsy moth.

. Gypsy moth is spreading at a faster rate than in the past and could infest much of the South and Midwest during the next 30 years (left map).

Slow the Spread

The purpose of the Slow the Spread Program (STS) is to slow the spread of the advancing gypsy moth population front using intensive monitoring to identify recently established, low-level populations in the transition area for possible treatment.

Slowing the spread would delay the damage and management costs associated with managing new infestation. A recent pilot project has demonstrated that the rate of gypsy moth spread could be slowed by at least 60 percent through application of the best technology to survey and manage incipient populations (right map).

Beginning in 1999, the USDA Forest Service, State partners and other USDA agencies anticipate national implementation of STS, contingent on availability of funds. Across the 1,200-mile gypsy moth frontier from Wisconsin to North Carolina, implementation of STS is expected to...

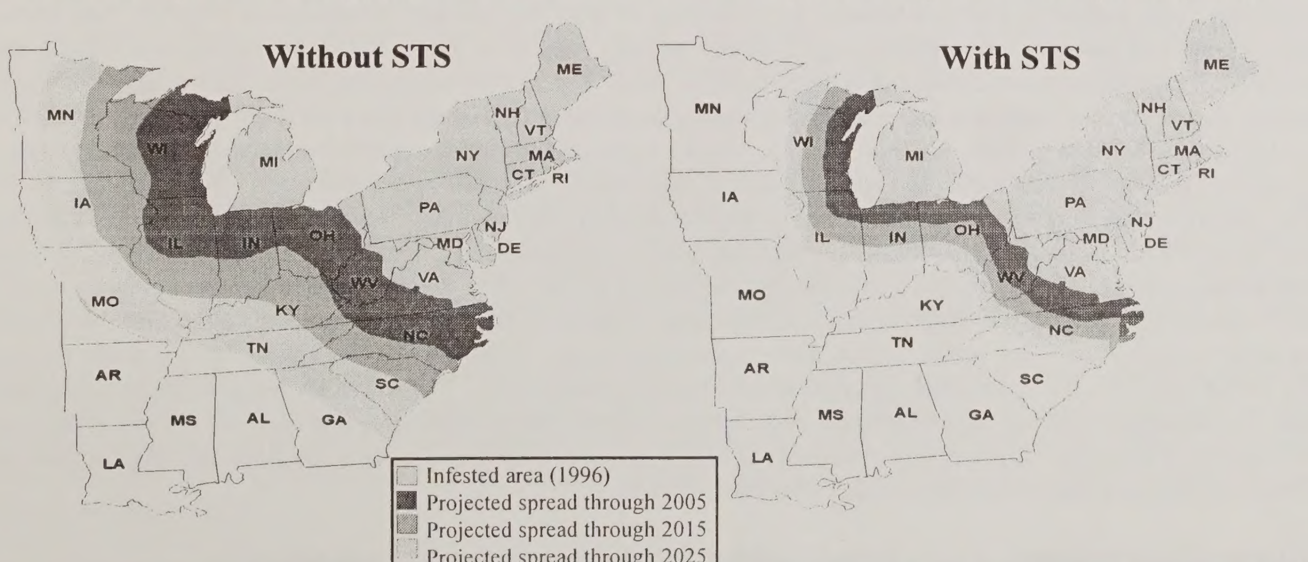
. Decrease the new territory invaded by the gypsy moth each year from 15,600 square miles to 6,000 square miles.

. Protect forests, forest-based industries, urban and rural parks, and private property.

. Avoid at least $22 million per year in damage and management costs.

For more information regarding Slow the Spread, contact Donna Leonard at the USDA Forest Service in Asheville, NC.

Estimated spread of the gypsy moth with and without implementing Slow the Spread (STS).



Historical Perspective Leading to the Slow the Spread Pilot Project

Richard C. Reardon

During the 1970's, State and Federal gypsy moth managers recognized the need to develop an integrated pest management (IPM) approach to manage the gypsy moth in the eastern United States. Between 1975 and 1978, the U.S. Department of Agriculture, initiated a multidisciplinary research, development and application program to elucidate the natural process operating against the gypsy moth and to further evaluate intervention activities for use against low-to-high density populations (McManus, 1978).

Several advances in technology were realized: 1) the use of the pheromone disparlure for disruption of mating and monitoring gypsy moth populations was demonstrated; 2) a prototype gypsy moth mass-rearing facility was developed at the APHIS Otis Methods Laboratory, MA, which provided quality insects; and 3) the biological (Gypchek) and chemical (diflubenzuron) insecticides were registered with the EPA. The development of these new tools and methodologies provided the impetus for the USDA Forest Service to initiate a pilot study of the feasibility of using an IPM approach to manage low-level gypsy moth populations at the leading edge of the infested area.

The first sustained attempt to manage the gypsy moth, embracing the concepts of integrated pest management (IPM), was initiated in 1983 in a four-county area in the State of Maryland. The Maryland Gypsy Moth IPM Pilot Project was a 5-year cooperative effort between the Maryland Department of Agriculture and the USDA Forest Service, State and Private Forestry. The stated goal of the project was to evaluate the feasibility of managing the gypsy moth at low levels over a wide range of ecological, geographical, and land use areas. The project area was divided into a treatment area where IPM was implemented and a comparison area where the standard operational Cooperative Suppression Program was applied. The project was structured around a comprehensive system of surveillance and biological monitoring designed to provide an annual database on the distribution and abundance of gypsy moth populations and their natural enemies. A monitoring system, consisting of pheromone traps and larval sampling devices, was overlaid throughout the project area on a 1-km fixed-point grid established on UTM coordinates. Data obtained from the monitoring grid were utilized by managers to identify areas where intervention actions—either more intensive egg mass surveys or suppression treatments—should be conducted in the following year. Major emphasis was placed on the continued development of gypsy moth specific suppression treatments. Although the benefits of preventive treatments were not demonstrated within the duration of the 5-year project because of regional declines in gypsy moth populations, the benefits realized from maintaining a fixed-point monitoring system were apparent. Areas where gypsy moth populations were increasing rapidly were readily identified, and labor-intensive egg mass surveys were allocated only to those areas where significant changes in trend occurred. Furthermore, a data management system was developed for the project that facilitated the processing of the large monitoring database, and Geographic Information System (GIS) computer technologies were utilized to produce practical graphic displays of data for decision-makers.

This project represented the first attempt to use pheromone traps to monitor low-level gypsy moth populations over a broad geographical area. Furthermore, the analysis of data amassed from the 1-km grid of traps over time demonstrated that less intensive trapping could be used to monitor adequately the distribution and trend in populations, thus reducing significantly the cost of surveillance. The protocols that were developed in the Maryland IPM Project were utilized with minor modifications in the Appalachian Integrated Pest Management Gypsy Moth (AIPM) Project (Reardon et al. 1993).

In 1987, Congress directed the Forest Service to continue efforts to manage the leading edge of gypsy moth populations along the Allegheny Mountains in Virginia and West Virginia. Therefore, the Forest Service established the AIPM Project, a 5-year effort which encompassed approximately 5 million hectares in 20 counties in West Virginia and 18 counties in Virginia. The AIPM Project area was divided into four zones based on pheromone trap catch and egg mass data. Protocols for monitoring and making decisions about the need for intervention activities were developed for each zone. The AIPM Project was structured around an intensive survey and monitoring system. Gypsy moth and forest stand data were entered into a GIS which was used to provide graphic and textual information for project decision makers. In Zone I and, to a lesser degree, Zone II of the AIPM Project area, potentially defoliating populations of the gypsy moth were numerous and consequently the aerial application of diflubenzuron (Dimilin®) and *Bacillus thuringiensis* (Btk) were the major intervention treatments implemented in these regions. The aerial application of Btk and Disrupt II were used in Zones III and IV against low-density populations to slow the spread and expansion of these populations. Methods development studies and special projects were an important component of the AIPM Project. Four intervention tactics were evaluated and refined: Gypchek®, Btk, mating disruption and mass trapping. Numerous studies were conducted concerning the biology, spread and population dynamics of the gypsy moth fungus, *Entomophaga maimaiga*. Also, studies were funded to document the impact of intervention tactics (Btk, diflubenzuron) and gypsy moth defoliation on non-targets. The AIPM Project provided many publications documenting the technology and methods developed, and implementation of the technologies and methods in current operational and eradication projects. Further development and evaluation of low-level survey and monitoring techniques and intervention tactics are being facilitated in the Slow the Spread Pilot Project (Reardon, 1996).

For more information and references, contact Richard Reardon, USDA Forest Service, Morgantown, WV.

Results from the Gypsy Moth Slow the Spread Pilot Project

A. Sharov, J. Mayo, and D. Leonard

Overview

Gypsy moth currently infests all or parts of seventeen states in the northeastern United States (Fig. 1). The transition area, a band 80 to 160 km wide separating the infested area from the uninfested area, is characterized by numerous, but distinct, low-density gypsy moth populations. When left untreated, these populations grow, coalesce and contribute to further spread. The USDA Cooperative Gypsy Moth Management Program includes strategies to manage gypsy moth in the infested and uninfested areas but does not include a strategy to manage gypsy moth in the transition area.

Spread rates have increased from approximately 3 km per year between 1916 - 1965 to more than 20 km per year between 1966-1990 (Liebhold et al., 1992). The authors speculated the increase was due mainly to short-range, artificial transport of life stages associated with the increased mobility of humans and goods. Results from the Appalachian Integrated Pest Management (AIPM) project suggested that management of low-density populations in the transition area had the potential to reduce the rate of spread. This led to the initiation of the Slow the Spread (STS) Pilot Project in 1993. The goal of STS is to determine the feasibility of using integrated pest management strategies to slow the spread of the gypsy moth over large geographical areas.

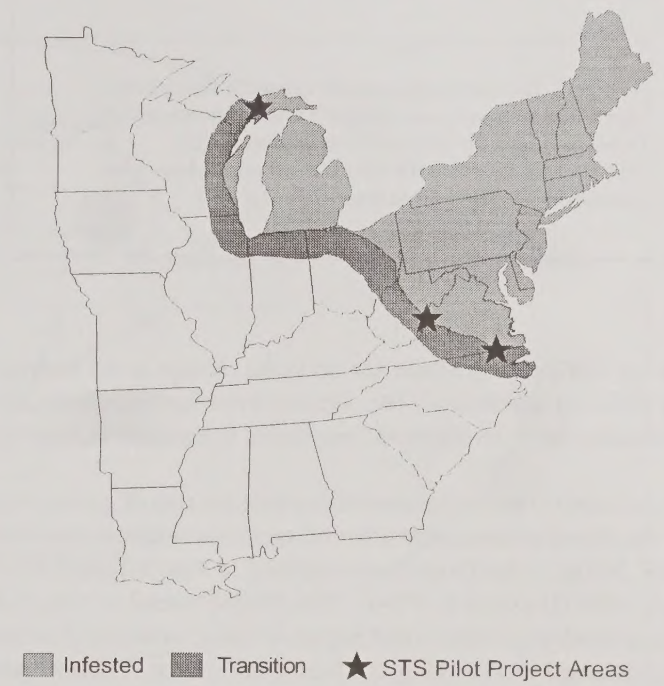


Figure 1: 1997 gypsy moth infestation status

STS uses intensive monitoring to locate recently established, low-density populations of the gypsy moth in the transition area of four States: North Carolina, Virginia, West Virginia, and Michigan. Once detected, populations are monitored and, if necessary, are treated. The implementation of STS has resulted in a 60 percent reduction in the rate of spread in the pilot project areas in the Appalachian Mountains. Assuming that a 60 percent reduction in spread could be achieved along the entire front, it has been estimated that full implementation of STS throughout the transition area will have a benefit/cost ratio of at least 2.78.

Project Methods and Results

The STS pilot project areas are each about 150-200 km in depth (Fig. 1). The 10 moth boundary line, which coincides approximately with the beginning of the transition area, bisects the STS areas into 2 roughly equal parts. The area in front of the 10 moth boundary, called the action zone, is where intensive monitoring (trap spacing of 2 km or 500 m) and treatments are conducted. The area behind the 10 moth boundary, called the evaluation zone, is monitored with widely spaced grids of traps (> 5 km spacing) in order to track the progression of the population front.

In order to determine if pest management activities in the transition area have reduced the rate of gypsy moth spread, STS and historic moth capture data sources were used to delineate population boundaries at six thresholds (1, 3, 10, 30, 100, and 300 moths per trap). The rate of spread was then calculated as the average distance between population boundaries of the same threshold in consecutive years (Sharov et al., 1995, 1996). The scarcity of historic male moth capture data from the transition or generally infested areas limited our evaluation of spread to the central Appalachian Mountains, the only area from which adequate data were available.

Treatments to suppress low-level populations of the gypsy moth in the transition area of the central Appalachians were initiated in 1990 as part of the AIPM project, and have continued in STS. Therefore, we evaluated the effect of combined project activities (AIPM + STS) on the rate of spread. We found the rate of spread in the central Appalachian Mountains was greater than 20 km per year between 1981-1990, but after 1990 when pest management activities were initiated in the transition area, it declined to an average of 8 km per year (Fig. 2).

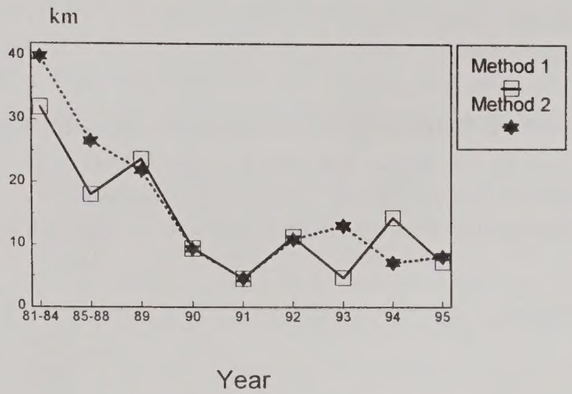


Figure 2. The rate of gypsy moth spread in the central Appalachian Mountains estimated from 6 thresholds of moth counts as the difference between averaged boundaries (the standard error for average spread rates in individual years varied from 1.4 to 2.1 km).

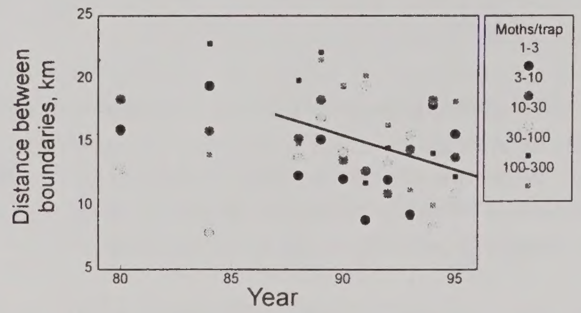


Figure 3. Boundary compression: the change in the distance between population boundaries estimated using thresholds of moth counts in neighboring areas.

A second method to evaluate spread is the change in the distance between adjacent population boundaries estimated in the same year using different thresholds. The distance between boundaries should decrease as the rate of spread decreases (boundary compression). The distance between adjacent boundaries in the central Appalachians declined in 1988-95 (Fig. 3).

Both measures support the conclusion that the rate of gypsy moth spread has declined in the central Appalachian Mountains. However, the decrease coincided with the appearance and spread of the fungal pathogen, *Entomophaga maimaiga* (Humber, Shimazu & Soper). Initially, the fungus was confined to New England where it caused widespread mortality in gypsy moth populations beginning in 1989 (Hajek et al. 1996). The fungus spread rapidly, but it was not until 1994 that it was recovered from the expanding front of gypsy moth populations and began to cause widespread mortality among larval populations. However, the rate of gypsy moth spread declined in 1990 (Fig. 2), four years earlier. This suggests that pest management activities (AIPM + STS), rather than the fungus, were primarily responsible for the reduction in spread between 1990-1994.

Modeling and Optimizing the STS Strategy

A model was developed that simulates the establishment and growth of isolated colonies beyond the generally infested area (Sharov and Liebhold, 1997). In nature, the number of colonies detected using pheromone traps decreases linearly with increasing distance from the population front (Fig. 4). In the model we assumed the probability of colony establishment also decreases with increasing distance from the front.

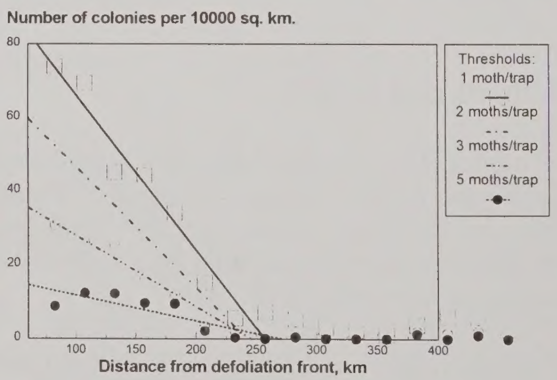


Figure 4. The number of gypsy moth colonies detected at varying distances from the population front using different detection thresholds.

To simulate the effect of the STS project, the model was modified to reflect that no new colonies were established in the transition area where STS is implemented. Under these conditions, the model predicted that the rate of spread should be reduced by 54 percent. The actual 60 percent reduction detected in the rate of gypsy moth spread (Fig. 2) was, therefore, quite close to the model's predicted rate of spread. The model also predicts that additional reductions in the rate of spread can only be accomplished by extending the area of intensive management into the leading edge of the generally infested area.

We then developed another model designed to optimize the density of traps used in grids for detecting isolated colonies and the criteria for selecting treatment areas in STS (Sharov et al., 1997). Model parameters were estimated using data from the STS project

area in the central Appalachians where a significant decline in spread had been previously documented. Optimization indicated trap density should decrease with increasing distance from the population front, from approximately 0.3 to 0.1 traps per km^2. As a result of this analysis, in 1996 we decreased trap density in the STS project areas by approximately 70%, to 0.3 traps per km^2. This action yielded significant savings with little or no decrease in the efficiency of detecting new infestations.

According to the model, the proportion of the project area targeted for intensive trapping (500 m grid spacing) or treatment, as well as the moth capture threshold which triggers these activities, should decrease as distance from the population front increases. If the distribution of moth counts is known at a specific distance, we can determine thresholds, T_1 and T_2, such that the probability of exceeding these thresholds equals the target proportion of areas where intensive trapping (ca. 5%) or treatment (ca. 0.5%) are needed. STS uses this algorithm (Fig. 5) to target management activities in the project areas. Use of the algorithm to facilitate decisionmaking streamlines the process considerably.

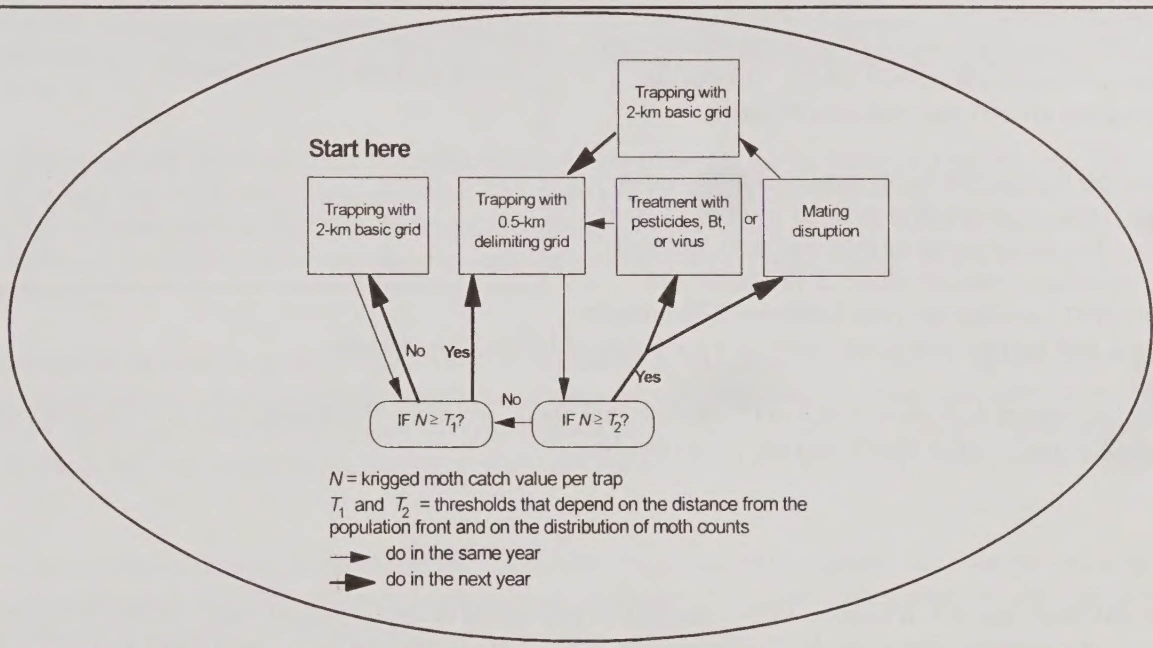


Figure 5. Decision algorithm used in the Slow the Spread pilot project

Benefits and Costs of STS and Implementation of a National Strategy

Estimating Benefits

The STS strategy has a solid economic justification based on delay of damage and management costs that will occur as gypsy moth spreads into previously uninfested areas. Leuschner (1991) and Leuschner et al. (1996) estimate the economic impacts over a 25 year period for various rates of spread. Leuschner (1991) accounts for gypsy moth impacts one time only in the first year of infestation (a conservative estimate), while Leuschner et al. (1996) includes yearly impacts over a 25 year period (a less conservative estimate). Using both methods provides a range of estimated yearly benefits that are attributable to a particular reduction in the rate of spread (Table 1). Program benefits are calculated as:

Table 1: Range of yearly benefits expected from implementing the STS strategy.

If rate of spread is reduced from 20 km per year to...	% reduction in spread	Range of yearly benefits is... (millions of dollars)
16	20	$10-81
12	40	$21-162
8	60	$34-264
4	80	$44-345

$$\text{Benefits} = \$\ \text{Impact}_{\text{spread without STS}} - \$\ \text{Impact}_{\text{spread with STS}}$$

Estimating Cost

Key assumptions that are used to estimate the costs of implementing STS across the entire transition area include (Mayo and Leonard, 1997):

- The area where STS will be implemented begins 10 km in advance of the 10 moth boundary line, is 100 km deep, and 1,920 km long;
- 95 percent of the STS area will be trapped using the base grid with trap spacing = 2 km;
- 5 percent of the STS area will be trapped using intensive grids with trap spacing = 0.5 km;
- 0.5 percent of the STS area will be treated annually.

We used a combination of actual protocols implemented under the pilot project and projections from the model to optimize STS as the basis for these assumptions. Under this scenario, a national STS program would cost approximately $12 million annually to implement.

Benefit: Cost Ratios

Benefit: Cost ratios were calculated based on projected costs of $12 million annually and estimated benefits from Leuschner (1991) and Leuschner et al. (1996) for various levels of program effectiveness. A ratio greater than 1.0 is cost effective (Table 2). All but the lowest levels of program effectiveness are cost effective.

Table 2: Benefit: Cost ratios for implementation of STS

Spread reduced from 20 KM per year to...	Reduction in spread	Benefit: Cost ratio calculated using... One time impacts	Yearly impacts
16	20%	0.93	3.60
12	40%	1.39	14.40
8	60%	2.78	21.60
4	80%	3.66	28.75

The introduction of the fungus into the dynamics of gypsy moth populations suggests that a conservative estimate of benefits from STS is appropriate. The conservative benefit/cost ratio for implementing STS and reducing spread by 60% is 2.78. Under this scenario, for a cost of $12 million per year, a national STS program would delay damage and management costs valued at a minimum of $34 million annually.

For more information, contact A. Sharov, Virginia Polytechnic and State University, Blacksburg, VA, J. Mayo, Clemson University, Clemson, SC, or D. Leonard, USDA Forest Service, Asheville, NC.

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Planning for Implementation of STS

Esther Chapman

The eight States located on the leading edge of the gypsy moth infested area have taken the lead in planning for implementation of the national Slow the Spread (STS) program in 1999. State leadership is needed if the national program is going to work successfully across political boundaries.

The State members on the STS Implementation Team include: Charles Coffman (West Virginia), Phil Eggborn (Virginia), Dave Madison (Ohio), Robert Waltz (Indiana), Ken Rauscher (Michigan) and Stan Smith (Illinois) along with Ester Chapman (Wisconsin, chair) and Bill Dickerson (NC Department of Agriculture, vice-chair). Federal agencies are represented by Coanne O'Hern (APHIS-PPQ) and Donna Leonard (USDA Forest Service), who will continue to participate on the Team.

There are several difficult administrative issues that must be resolved early in 1998. We need to design an organizational structure that is functional and that supports a decision-making process that is based on biology, and that has a regional perspective while recognizing political realities. It must allocate Federal funds to where they are needed most without jeopardizing current State financial support.

Dickerson, who has been actively involved in the STS pilot project and in planning for the national program said, "We've worked for over a year on developing a sound organizational structure. There are two proposals currently being considered: One is modeled after the structure used to implement the Boll Weevil Eradication Program and calls for creating a private, nonprofit corporation (a Foundation) to funnel Federal funds to the States; the other uses the existing Federal grant process with a steering committee making funding recommendations."

The next Team meeting will be held on January 12-13, 1998, in Indianapolis, IN. Items on the agenda include approving bylaws for the organization, reviewing proposed organizational charts and responsibilities, nominating various committee members and collecting 1998 data. Future agendas will include the review of STS program standards and guidelines (using the pilot project final report as a starting point), standards for funding decisions, State cost-share and budget issues and the coordination of STS with APHIS programs.

Members of the Team are still considering the pros and cons of the two organizational proposals, but I am very excited about implementing a regional program using the STS models and management strategies. It is refreshing to see a Federal agency promote a new approach to pest management using the latest technology and biological knowledge.

For more information, contact Esther Chapman, Wisconsin Department of Agriculture, Madison, WI.

The Current Decline in Gypsy Moth Outbreaks and its Significance to the Slow the Spread Project

Andrew Liebhold and Alexei Sharov

As the gypsy moth slowly expands its range through North America, gypsy moth outbreaks are common in recently infested areas (ca. 5 years following the initial establishment of populations). Typically this initial outbreak collapses after 1, 2, or 3 years and populations may then remain at sparse densities for several years. But the occurrence of the initial outbreak does not preclude future outbreaks. The onset of subsequent outbreaks may occur with some regularity (e.g. periodic) or outbreaks may reoccur irregularly (Figure 1).

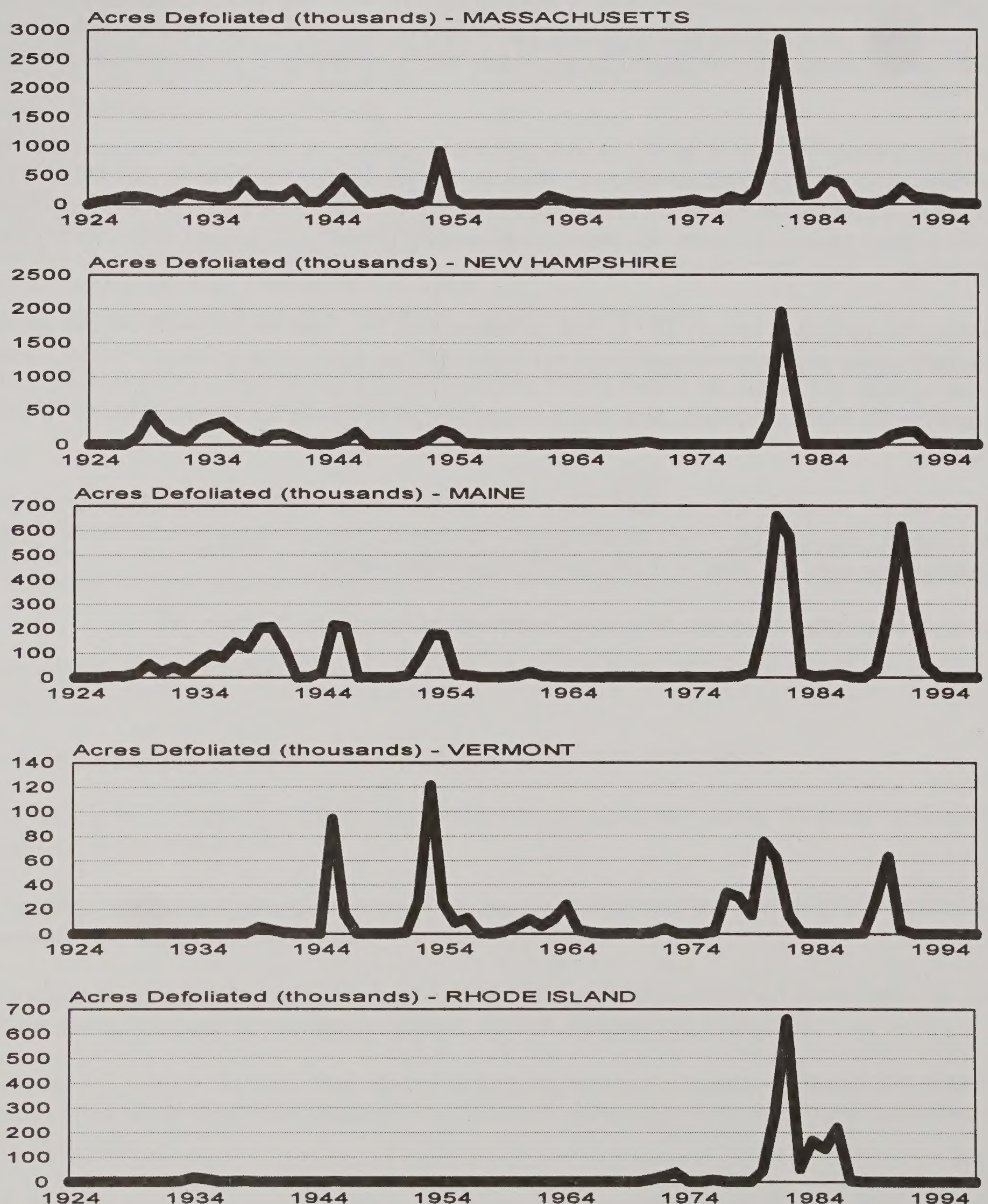

Figure 1. Historical records of gypsy moth defoliation in the New England States.

Outbreak populations occurred over large portions of the northeastern US in the early 1980's and again in the early 1990's (Figure 1). Currently, populations are at relatively low levels throughout most of the Northeastern Region and only negligible defoliation has been recorded over the past three years. The reasons for this current decline in populations are not well understood. Larval mortality caused by the fungal pathogen, *Entomaphaga maimaiga,* has been common during the last five years and because this pathogen was apparently not present until recently, it has been suggested that the current decline in gypsy moth populations has been caused by this agent. However, there is no scientific evidence to support such a conclusion since detailed survivorship data and data on the impact of *E. maimaiga* on populations are lacking from most populations. We will probably not understand completely the manner in which this pathogen affects the dynamics of gypsy moth populations until we have had 20-30 years to observe its effects relative to other mortality agents during various phases of the outbreak cycle. The current decline in outbreaks is not unprecedented (Figure 1) and there is no reason to believe that *E. maimaiga* or any other mortality factor will prevent the recurrence of another large regional gypsy moth outbreak in the future.

Grids of pheromone traps have been placed along the front of the advancing gypsy moth population for many years. Data recovered from these traps indicate to us that the spread of the advancing population front is not a smooth, continuous process. Rather, it appears that isolated gypsy moth colonies arise beyond the infested front and these colonies expand in size and eventually coalesce, thus resulting in a much faster rate of spread than would be anticipated.

The process by which isolated colonies are formed is not thoroughly understood. New infestations might be caused by wind-borne dispersal of large numbers of first instars from outbreak areas; however, this now appears unlikely based upon our limited knowledge of gypsy moth dispersal. Instead, it appears likely that these colonies are formed by inadvertent transport of life stages by humans. We know that during gypsy moth outbreaks, it is not uncommon for large numbers of different life stages, in particular, egg masses, to become associated with objects (motor vehicles, trailers, logs, etc.) that are transported by humans and these life stages may survive to produce new populations in previously uninfested areas.

The strategy behind the slow the spread project is to reduce the rate of gypsy moth range expansion by finding new isolated colonies (using grids of pheromone traps in the uninfested area just beyond the expanding front) and either eradicating them or greatly reducing their size. Since most of these isolated colonies probably originate from outbreak populations, it is likely that the current decline of outbreaks may result in a decline in the number of new isolated infestations, and thus this may contribute to reduction in gypsy moth spread even without any intervention. Indeed, the interception of gypsy moths at border inspection stations and the abundance of new infestations in extremely isolated areas (e.g., California, Washington) has been shown to be related to yearly trends in defoliation in the generally infested area (though there may be a lag of 4-5 years).

Does this mean that the STS project is unnecessary and that gypsy moth spread will decline on its own? We believe that the answer to this question is no because the current decline in gypsy moth outbreaks is probably only temporary and the effect on spread is likely to be minimal. Gypsy moth outbreak populations have declined before, yet, large, regional outbreaks have returned in the past (Figure 1). The decline in outbreaks may result in a slight decrease in the number of isolated colonies that are initiated; however, there is no reason to expect that population growth near the expanding front is likely to decline. Factors that affect the dynamics of established populations are not necessarily also important along the leading edge. Recent data from STS and elsewhere indicate that leading edge populations in Wisconsin, Illinois, Indiana, and Ohio have been growing rapidly over the last few years even though outbreak populations in the northeast (including Michigan) have subsided.

Another reason why it is important to maintain the activities associated with the STS program is that the decline in outbreak populations allows us to more effectively identify isolated populations using grids of pheromone traps. In previous years, males emanating from outbreak populations in the generally infested area have dispersed long distances and become trapped in grids of pheromone traps in largely uninfested portions of Michigan, Wisconsin and North Carolina. These dispersal episodes made it extremely difficult to identify isolated colonies in these areas because the immigrant males could not be differentiated from those originating from local populations. The current lull in gypsy moth outbreaks has apparently caused this problem (dispersal of males) to diminish greatly in recent years. Given this lull in outbreak populations, now is an excellent time to collect data from trap grids--the data should help increase the efficacy of the STS program in the future.

For more information, contact Andrew Liebhold, USDA Forest Service, Morgantown, WV, or Alexei Sharov, Department of Entomology, Virginia Polytechnic and State University, Blacksburg, VA.

Attention Gypsy Moth Experts

Our next issue of the Gypsy Moth News will feature the Directory of Expertise which appeared in Issue No. 40. If we missed you the first time around or if you have any corrections, please let us know by March 16, 1998. Send us your name, organization, phone number, e-mail address, and areas of expertise related to gypsy moth at the following address:

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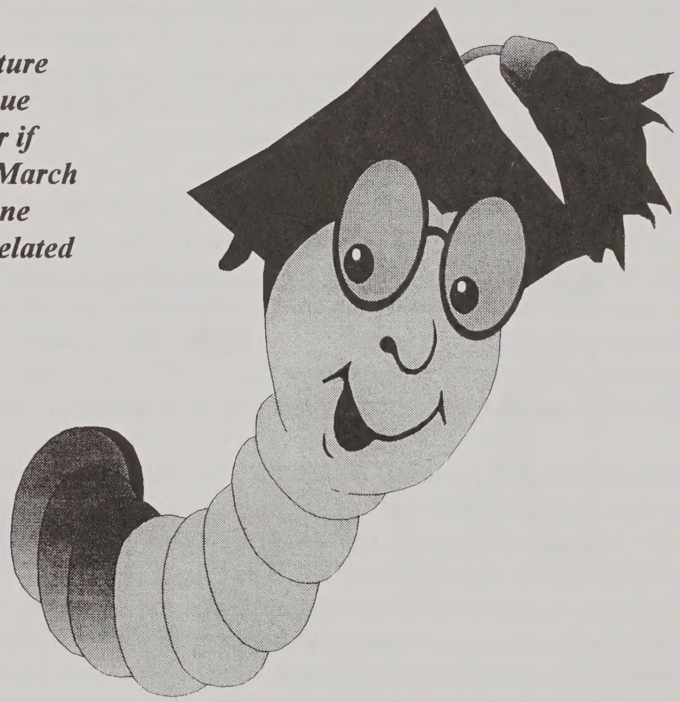

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